

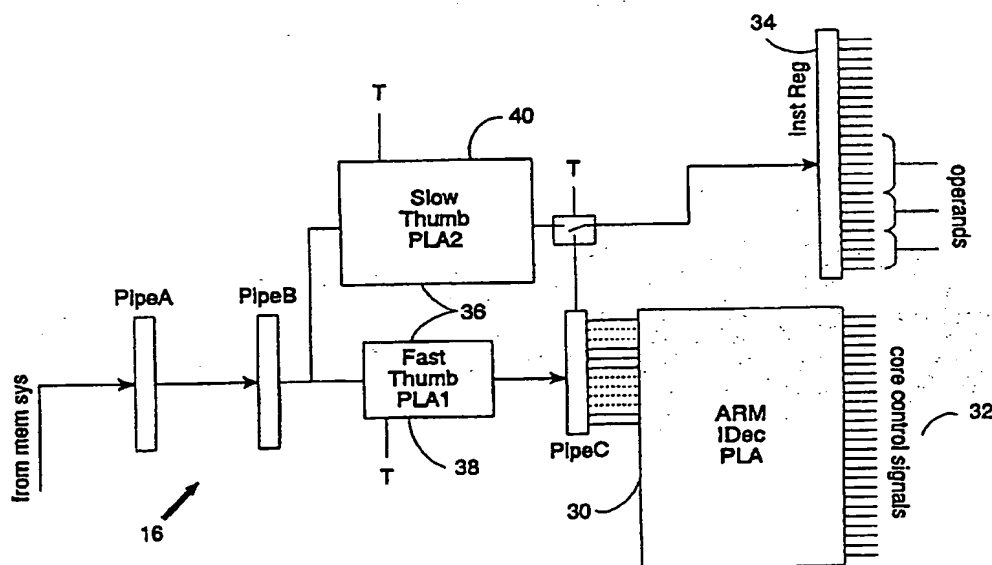
PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau

## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>G06F 9/318</b>	<b>A1</b>	(11) International Publication Number: <b>WO 95/30187</b> (43) International Publication Date: 9 November 1995 (09.11.95)
(21) International Application Number: PCT/GB95/00314 (22) International Filing Date: 15 February 1995 (15.02.95) (30) Priority Data: 9408873.9                      3 May 1994 (03.05.94)                      GB (71) Applicant: ADVANCED RISC MACHINES LIMITED [GB/GB]; Fulbourn Road, Cherry Hinton, Cambridge CB1 4JN (GB). (72) Inventor: JAGGAR, David, Vivian; 48 Mandrill Close, Cherry Hinton, Cambridge CB1 4TN (GB). (74) Agents: ROBINSON, Nigel, Alexander, Julian et al.; D. Young & Co., 21 New Fetter Lane, London EC4A 1DA (GB).	(81) Designated States: CN, JP, KR, RU, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.</i>	

(54) Title: MULTIPLE INSTRUCTION SET MAPPING



## (57) Abstract

A data processing system is described utilising multiple instruction sets. The program instruction words are supplied to a processor core (2) via an instruction pipeline (6). As program instruction words of a second instruction set pass along the instruction pipeline, they are mapped to program instruction words of the first instruction set. The second instruction set has program instruction words of a smaller bit size than those of the first instruction set and is a subset of the first instruction set. Smaller bit size improves code density, whilst the nature of the second instruction set as a subset of the first instruction set enables a one-to-one mapping to be efficiently performed and so avoid the need for a dedicated instruction decoder for the second instruction set.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgyzstan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo	KR	Republic of Korea	SE	Sweden
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LI	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LU	Luxembourg	TD	Chad
CS	Czechoslovakia	LV	Latvia	TG	Togo
CZ	Czech Republic	MC	Monaco	TJ	Tajikistan
DE	Germany	MD	Republic of Moldova	TT	Trinidad and Tobago
DK	Denmark	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	US	United States of America
FI	Finland	MN	Mongolia	UZ	Uzbekistan
FR	France			VN	Viet Nam
GA	Gabon				

MULTIPLE INSTRUCTION SET MAPPING

This invention relates to the field of data processing. More particularly, this invention relates to data processing using multiple sets of program instruction words.

Data processing systems operate with a processor core acting under control of program instruction words, which when decoded serve to generate core control signals to control the different elements with the processor to perform the necessary operations to achieve the processing specified in the program instruction word.

It is known to provide systems that operate with more than one instruction set (e.g. the VAX11 computers of Digital Equipment Corporation have a VAX instruction mode and a compatibility mode that enables them to decode the instructions for the earlier PDP11 computers). Such systems have typically incorporated a separate instruction decoder for each instruction set. Instruction decoders are relatively complex and large circuit elements.

The space that an integrated circuit occupies is at a premium. The smaller an integrated circuit is, the less expensive it will be to manufacture and the higher the manufacturing yield. In addition, additional space will be made available upon the integrated circuit for use by other circuit elements. Measures that reduce the size of an integrated circuit are strongly advantageous.

Viewed from one aspect this invention provides apparatus for processing data, said apparatus comprising:

a processor core responsive to a plurality of core control signals;

decoding means for decoding P bits of an X-bit program instruction word of a first instruction set to generate said core control signals;

an instruction pipeline through which instruction program words are passed to said decoding means; and

first mapping means responsive to a Y-bit program instruction word of a second instruction set passing along said instruction pipeline for mapping Q bits of said Y-bit program instruction word to said P bits of a corresponding X-bit program instruction word for decoding by said decoding means, wherein

Y is less than X, and said second instruction set is a subset of said first instruction set.

5 The invention operates with systems incorporating an instruction pipeline and serves to map instructions from a second instruction set to a first instruction set as they pass along the instruction pipeline. Translating the program instruction words from a second instruction set to those of a first instruction set avoids the need for a second instruction decoder and enables a simpler and more efficient embodiment of the rest of the processor core. The invention recognises that if  
10 the second instruction set is made to be a subset of the first instruction set, then a one to one mapping is possible and this may be achieved in a sufficiently regular and quick manner so as not to restrict system performance. Furthermore, the invention recognises that only some of the bits of the instructions from the second  
15 instruction set need to be mapped to corresponding bits of instruction words within the first instruction set to actually drive the decoding means. This increases the speed at which the mapping may be performed.

The speed of instruction decoding is enhanced in preferred embodiments by the provision of an instruction register for holding an  
20 X-bit instruction being executed by said processor core, said processor core reading operand values from said instruction register.

In this way, the operands from within an instruction which do not require decoding by an instruction decoder but merely acting upon by the processor core, can be directly read from the instruction rather  
25 than having to pass through the instruction decoder.

In order to facilitate this arrangement whereby the critical P bits needed for driving the decoding means are generated rapidly and yet the full X-bit program instruction word is subsequently generated for unmodified use by the processor core, preferred embodiments of the  
30 invention comprise second mapping means for mapping operand values within said Y-bit program instruction word within said instruction pipeline to corresponding positions within said corresponding X-bit program instruction word and storing said mapped operand values in said instruction register for use by said processor core.

35 The second mapping means could merely serve to map those operand values that are required by the processor core. However, the design of the instruction decoders can be effectively separated from that of the

processor core, and so facilitate future independent change of either, by providing that said second mapping means maps said Y-bit program instruction word to a complete version of said corresponding X-bit program instruction word and stores said complete version of said corresponding X-bit program instruction word in said instruction register.

It is usual that certain timing limits are imposed upon the decoding mechanisms as the program instruction words pass along the instruction pipeline. In order to more readily integrate with the existing hardware, in preferred embodiments instruction program words pass through said instruction pipeline over a plurality of processing cycles, one of said processing cycles being a decode cycle, said decoding means being operative to produce said core control signals by the end of said decode cycle and said first mapping means being operative to produce said P-bit of said corresponding X-bit program instruction word during a first portion of said decode portion to enable said decoding means still to produce said core control signals by the end of said decode cycle.

The feature that only some of the bits of the Y-bit program instruction word need to be mapped to drive the decoding means enables such timing requirements to be met.

An associated requirement that is less rigorous is that of when the operand values must be available. Preferred embodiments of the invention make use of this more relaxed requirement by providing that said second mapping means is operative to store said mapped operand values in said instruction register by the end of said decode cycle.

It will be appreciated that the operation of the first mapping means and the second mapping means may be made independent. The overall performance of the system is consequently improved if they operate in parallel.

The smaller size of the program instruction words of the second instruction set requires a modification of the functions that may be provided. It is preferred that the system be arranged such that said processor core has a plurality of registers used by said first instruction set and defined as register operands within some of said X-bit program instruction words and said second instruction set uses a subset of said registers defined as register operands within some of

said Y-bit program instruction words.

5 The use by the second instruction set of a subset of the registers used by the first instruction set enables a one to one mapping between instructions still to be achieved and yet provides for the smaller bit sizes of the second instruction set.

10 In order to deal with the different manner of handling the registers between the instruction sets, said second mapping means extends said register operands of said Y-bit program instruction words to produce said register operands of said X-bit program instruction words.

In a similar manner, other operands within the second instruction set have a reduced range compared to those of the first instruction set and are zero extended at their high order end during mapping by the second mapping means.

15 Viewed from another aspect the invention provides a method of processing data, said method comprising the steps of:

a processor core responsive to a plurality of core control signals;

20 decoding P bits of an X-bit program instruction word of a first instruction set with a decoding means to generate core control signals for controlling a processor core;

passing instruction program words through an instruction pipeline through to said decoding means; and

25 mapping Q bits of a Y-bit program instruction word of a second instruction set passing along said instruction pipeline to said P bits of a corresponding X-bit program instruction word for decoding by said decoding means, wherein

Y is less than X, and said second instruction set is a subset of said first instruction set.

30 An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 schematically illustrates a data processing apparatus incorporating a processor core and a memory system;

35 Figure 2 schematically illustrates an instruction and instruction decoder for a system having a single instruction set;

Figure 3 illustrates an instruction pipeline and instruction decoders for use in a system having two instruction sets;

Figure 4 illustrates the decoding of an X-bit program instruction word;

Figures 5 and 6 illustrate the mapping of Y-bit program instruction words to X-bit program instruction words;

5 Figure 7 illustrates an X-bit instruction set;

Figure 8 illustrates a Y-bit instruction set; and

Figure 9 illustrates the processing registers available to the first instruction set and the second instruction set.

10 Figure 1 illustrates a data processing system (that is formed as part of an integrated circuit) comprising a processor core 2 coupled to a Y-bit memory system 4. In this case, Y is equal to 16.

The processor core 2 includes a register bank 6, a Booths multiplier 8, a barrel shifter 10, a 32-bit arithmetic logic unit 12 and a write data register 14. Interposed between the processor core 2 and the memory system 4 is an instruction pipeline 16, an instruction decoder 18 and a read data register 20. A program counter register 22, which is part of the processor core 2, is shown addressing the memory system 4. A program counter incrementer 24 serves to increment the program counter value within the program counter register 22 as each instruction is executed and a new instruction must be fetched for the instruction pipeline 16.

20 The processor core 2 incorporates N-bit data pathways (in this case 32-bit data pathways) between the various functional units. In operation, instructions within the instruction pipeline 16 are decoded by the instruction decoder 18 which produces various core control signals that are passed to the different functional elements within the processor core 2. In response to these core control signals, the different portions of the processor core conduct 32-bit processing operations, such as 32-bit multiplication, 32-bit addition and 32-bit logical operations.

30 The register bank 6 includes a current programming status register 26 and a saved programming status register 28. The current programming status register 26 holds various condition and status flags for the processor core 2. These flags may include processing mode flags (e.g. system mode, user mode, memory abort mode etc.) as well as flags indicating the occurrence of zero results in arithmetic operations, carries and the like. The saved programming status

35

register 28 (which may be one of a banked plurality of such saved programming status registers) is used to temporarily store the contents of the current programming status register 26 if an exception occurs that triggers a processing mode switch. In this way, exception handling can be made faster and more efficient.

Included within the current programming status register 26 is an instruction set flag T. This instruction set flag is supplied to the instruction decoder 18 and the program counter incrementer 24. When this instruction set flag T is set, the system operates with the instructions of the second instruction set (i.e. Y-bit program instruction words, in this case 16-bit program instruction words). The instruction set flag T controls the program counter incrementer 24 to adopt a smaller increment step when operated with the second instruction set. This is consistent with the program instruction words of the second instruction set being smaller and so more closely spaced within the memory locations of the memory system 4.

As previously mentioned, the memory system 4 is a 16-bit memory system connected via 16-bit data buses to the read data register 20 and the instruction pipeline 16. Such 16-bit memory systems are simpler and inexpensive relative to higher performance 32-bit memory systems. Using such a 16-bit memory system, 16-bit program instruction words can be fetched in a single cycle. However, if 32-bit instructions from the second instruction set are to be used (as indicated by the instruction set flag T), then two instruction fetches are required to recover a single 32-bit instruction for the instruction pipeline 16.

Once the required program instruction words have been recovered from the memory system 4, they are decoded by the instruction decoder 18 and initiate 32-bit processing within the processor core 2 irrespective of whether the instructions are 16-bit instructions or 32-bit instructions.

The instruction decoder 18 is illustrated in Figure 1 as a single block. However, in order to deal with more than one instruction set, the instruction decoder 18 has a more complicated structure as will be discussed in relation to Figures 2 and 3.

Figure 2 illustrates the instruction pipeline 16 and an instruction decoder 18 for coping with a single instruction set. In this case, the instruction decoder 18 includes only a first decoding



means 30 that is operative to decode 32-bit instructions. This decoding means 30 decodes the first instruction set (the ARM instruction set) utilising a programmable logic array (PLA) to produce a plurality of core control signals 32 that are fed to the processor core 2. The program instruction word which is currently decoded (i.e. yields the current the core control signals 32) is also held within an instruction register 34. Functional elements within the processor core 2 (e.g. the Booths multiplier 8 or the register bank 6) read operands needed for their processing operation directly from this instruction register 34.

A feature of the operation of such an arrangement is that the first decoding means 30 requires certain of its inputs (the P bits shown as solid lines emerging from the PipeC pipeline stage) early in the clock cycle in which the first decoding means operates. This is to ensure that the core control signals 32 are generated in time to drive the necessary elements within the processor core 2. The first decoding means 30 is a relatively large and slow programmable logic array structure and so such timing considerations are important.

The design of such programmable logic array structures to perform instruction decoding is conventional within the art. A set of inputs are defined together with the desired outputs to be generated from those inputs. Commercially available software is then used to devise a PLA structure that will generate the specified set of outputs from the specified set of inputs.

Figure 3 illustrates the system of Figure 2 modified to deal with decoding a first instruction set and a second instruction set. When the first instruction set is selected by the instruction set flag T, then the system operates as described in relation to Figure 2. When the instruction set flag T indicates that the instructions in the instruction pipeline 16 are from the second instruction set, a second decoding means 36 becomes active.

This second decoding means decodes the 16-bit instructions (the Thumb instructions) utilising a fast PLA 38 and a parallel slow PLA 40. The fast PLA 38 serves to map a subset (Q bits) of the bits of the 16-bit Thumb instructions to the P bits of the corresponding 32-bit ARM instructions that are required to drive the first decoding means 30. Since a relatively small number of bits are required to undergo this

mapping, the fast PLA 38 can be relatively shallow and so operate quickly enough to allow the first decoding means sufficient time to generate the core control signals 32 in response to the contents of PipeC. The fast PLA 38 can be considered to act to "fake" the critical bits of a corresponding 32-bit instruction for the first decoding means without spending any unnecessary time mapping the full instruction.

However, the full 32-bit instruction is still required by the processor core 2 if it is to be able to operate without radical alterations and significant additional circuit elements. With the time critical mapping having been taken care of by the fast PLA 38, the slow PLA 40 connected in parallel serves to map the 16-bit instruction to the corresponding 32-bit instruction and place this into the instruction register 34. This more complicated mapping may take place over the full time it takes the fast PLA 38 and the first decoding means 30 to operate. The important factor is that the 32-bit instruction should be present within the instruction register 34 in sufficient time for any operands to be read therefrom in response to the core control signals 32 acting upon the processor core 2.

It will be appreciated that the overall action of the system of Figure 3 when decoding the second instruction set is to translate 16-bit instructions from the second instruction set to 32-bit instructions from the first instruction set as they progress along the instruction pipeline 16. This is rendered a practical possibility by making the second instruction set a subset of a first instruction set so as to ensure that there is a one to one mapping of instructions from the second instructions set into instructions within the first instruction set.

The provision of the instruction set flag T enables the second instruction set to be non-orthogonal to the first instruction set. This is particularly useful in circumstances where the first instruction set is an existing instruction set without any free bits that could be used to enable an orthogonal further instruction set to be detected and decoded.

Figure 4 illustrates the decoding of a 32-bit instruction. At the top of Figure 4 successive processing clock cycles are illustrated in which a fetch operation, a decode operation and finally an execute operation performed. If the particular instruction so requires (e.g.

a multiply instruction), then one or more additional execute cycles may be added.

A 32-bit instruction 42 is composed of a plurality of different fields. The boundaries between these fields will differ for differing instructions as will be shown later in Figure 7.

Some of the bits within the instruction 42 require decoding within a primary decode phase. These P bits are bits 4 to 7, 20 and 22 to 27. These are the bits that are required by the first decoding means 30 and that must be "faked" by the fast PLA 38. These bits must be applied to the first decoding means and decoded thereby to generate appropriate core control signals 32 by the end of the first part of the decode cycle. Decoding of the full instruction can, if necessary, take as long as the end of decode cycle. At the end of the decode cycle, operands within the instruction are read from the instruction register 34 by the processor 2 during the execute cycle. These operands may be register specifiers, offsets or other variables.

Figure 5 shows the mapping of an example of 16-bit instruction to a 32-bit instruction. The thick lines originate from the Q bits within the 16-bit instruction that require mapping into the P bits within the 32-bit instruction so that they may be applied to the first decoding means 30. It will be seen that the majority of these bits are either copied straight across or involve a simple mapping. The operands Rn', Rd and Immediate within the 16-bit instruction require padding at their most significant end with zeros to fill the 32-bit instruction. This padding is needed as a result of the 32-bit instruction operands having a greater range than the 16-bit instruction operands.

It will be seen from the generalised form of the 32-bit instruction given at the bottom of Figure 5, that the 32-bit instruction allows considerably more flexibility than the subset of that instruction that is represented by the 16-bit instruction. For example, the 32-bit instructions are preceded by condition codes Cond that renders the instruction conditionally executable. In contrast, the 16-bit instructions do not carry any condition codes in themselves and the condition codes of the 32-bit instructions to which they are mapped are set to a value of "1110" that is equivalent to the conditional execution state "always".

Figure 6 illustrates another such instruction mapping. The 16-

bit instruction in this case is a different type of Load/Store instruction to that illustrated in Figure 5. However, this instruction is still a subset of the single data transfer instruction of the 32-bit instruction set.

5           Figure 7 schematically illustrates the formats of the eleven different types of instruction for the 32-bit instruction set. These instructions are in turn:

1.     Data processing PSR transfer;
- 10    2.     Multiply;
3.     Single data swap;
4.     Single data transfer;
5.     Undefined;
6.     Block data transfer;
- 15    7.     Branch;
8.     Co-processor data transfer;
9.     Co-processor data operation; and
10.    Co-processor register transfer.
11.    Software interrupt.

20

A full description of this instruction set may be found in the Data Sheet of the ARM6 processor produced by Advanced RISC Machines Limited. The instruction highlighted within Figure 7 is that illustrated in Figures 5 and 6.

25           Figure 8 illustrates the 16-bit instruction set that is provided in addition to the 32-bit instruction set. The instructions highlighted within this instruction set are those illustrated in Figures 5 and 6 respectively. The instructions within this 16-bit instruction set have been chosen such that they may all be mapped to a

30   single 32-bit instruction and so form a subset of the 32-bit instruction set.

Passing in turn between each of the instructions in this instruction set, the formats specify the following:

35   Format 1:       Op = 0,1. Both ops set the condition code flags.  
                     0: ADD Rd, Rs, #Immediate3  
                     1: SUB Rd, Rs, #Immediate3

Format 2:       Op = 0,1. Both ops set the condition code flags.

- 0: ADD Rd, Rm, Rn  
1: SUB Rd, Rm, Rn
- 5      Format 3:      3 opcodes. Used to build large immediates.  
                     1 = ADD Rd, Rd, #Immediate 8<<8  
                     2 = ADD Rd, Rd, #Immediate 8<<16  
                     3 = ADD Rd, Rd, #Immediate 8<<24
- 10      Format 4:      Op gives 3 opcodes, all operations are MOVs Rd, Rs SHIFT  
                     #Immediate5, where SHIFT is  
                     0 is LSL  
                     1 is LSR  
                     2 is ASR  
                     Shifts by zero as defined on ARM.
- 15      Format 5:      Op1\*8+Op2 gives 32 ALU opcodes, Rd = Rd op Rn. All  
                     operations set the condition code flags.  
                     The operations are  
20                    AND, OR, EOR, BIC (AND NOT), NEGATE, CMP, CMN, MUL  
                     TST, TEQ, MOV, MVN(NOT), LSL, LSR, ASR, ROR  
                     Missing ADC, SBC, MULL  
                     Shifts by zero and greater than 31 as defined on ARM
- 25      8 special opcodes, LO specifies Reg 0-7, HI specifies a  
                     register 8-15  
                     SPECIAL is CPSR or SPSR  
                     MOV        HI, LO (move hidden register to visible  
                                     register)  
                     MOV        LO, HI (move visible register to hidden  
30                    register)  
                     MOV        HI, HI (eg procedure return)  
                     MOVs       HI, HI (eg exception return)  
                     MOVs       HI, LO (eg interrupt return, could be SUBS,  
                                     HI, HI, #4)  
35                    MOV        SPECIAL, LO (MSR)  
                     MOV        LO, SPECIAL (MRS)  
                     CMP        HI, HI (stack limit check)
- 40      8 free opcodes
- 45      Format 6:      Op gives 4 opcodes. All operations set the condition  
                     code flags  
                     0: MOV Rd, #Immediate 8  
                     1: CMP Rs, #Immediate 8  
                     2: ADD Rd, Rd, #Immediate 8  
                     It is possible to trade ADD for ADD Rd, Rs, #Immediate5
- 50      Format 7:      Loads a word PC + Offset (256 words, 1024 bytes). Note  
                     the offset must be word aligned.  
                     LDR Rd, [PC, #+1024]  
                     This instruction is used to access the next literal  
                     pool, to load constants, addresses etc.
- 55      Format 8:      Load and Store Word from SP (r7) + 256 words (1024  
                     bytes)  
                     Load and Store Byte from SP(r7) + 256 bytes

LDRD Rd,[SP,#+1024)

LDRB Rd,[SP,#+256]

These instructions are for stack and frame access.

5       Format 9:       Load and Store Word (or Byte), signed 3 bit Immediate Offset (Post Inc/Dec), Forced Writeback  
L is Load/Store, U is Up/Down (add/subtract offset), B is Byte/Word

10       LDR {B} Rd, [Rb],#+/-Offset3

STR {B} Rd, [Rb],#+/-Offset3

These instructions are intended for array access

The offset encodes 0 - 7 for bytes and 0, 4 - 28 for words

15       Format 10:     Load and Store Word (or Byte) with signed Register Offset (Pre Inc/Dec), No writeback  
L is Load/Store, U is Up/Down (add/subtract offset), B is Byte/Word

20       LDR       Rd,[Rb, +/-Ro, LSL#2]

STR       Rd,[Rb, +/-Ro, LSL#2]

LDRB      Rd,[Rb, +/-Ro]

STRB      Rd,[Rb, +/-Ro]

25       These instructions are intended for base + offset pointer access, and combined with the 8-bit MOV, ADD, SUB give fairly quick immediate offset access.

30       Format 11:     Load and Store Word (or Byte) with signed 5 bit Immediate Offset (Pre Inc/Dec), No Writeback  
L is Load/Store B is Byte/Word

LDR{B} Rd, [Rb,#+Offset5]

STR{B} Rd, [Rb,#+Offset5]

These instructions are intended for structure access

The offset encodes 0 - 31 for bytes and 0, 4 - 124 for words

35       Format 12:     Load and Store Multiple (Forced Writeback)

LDMIA Rb!, {Rlist}

STMIA Rb!, {Rlist}

Rlist specify registers r0-r7

40       A sub-class of these instructions are a pair of subroutine call and return instructions.

For LDM if r7 is the base and bit 7 is set in rlist, the PC is loaded

45       For STM if r7 is the base and bit 7 is set in rlist, the LR is stored

If r7 is used as the base register, sp is used instead

In both cases a Full Descending Stack is implemented ie

LDM is like ARM's LDMFD, STM is like ARM's STMFD

So for block copy, use r7 as the end pointer

50       If r7 is not the base, LDM and STM is like ARMs LDMIA, STMIA

55       Format 13:     Load address. This instruction adds an 8 bit unsigned constant to either the PC or the stack pointer and stores the results in the destination register.

ADD       Rd, sp, + 256 bytes

ADD Rd, pc, + 256 words (1024 bytes)  
The SP bit indicates if the SP or the PC is the source.  
If SP is the source, and r7 is specified as the  
destination register, SP is used as the destination  
register.

5

Format 14: Conditional branch, +/- 128 bytes, where cond defines  
the condition code (as on ARM) cond = 15 encodes as SWI  
(only 256, should be plenty).

10

Format 15: Sets bits 22:12 of a long branch and link. MOV lr,  
#offset << 12.

15

Format 16: Performs a long branch and link. Operation is SUB  
newlr, pc, #4; ORR pc, oldlr, #offset <<1. newlr and  
oldlr mean the lr register before and after the  
operation.

20

As previously mentioned, the 16-bit instruction set has reduced  
operand ranges compared to the 32-bit instruction set. Commensurate  
with this, the 16-bit instruction set uses a subset of the registers 6  
(see Figure 1) that are provided for the full 32-bit instruction set.  
Figure 9 illustrates the subset of registers that are used by the 16-  
bit instruction set.

CLAIMS

1. Apparatus for processing data, said apparatus comprising:  
a processor core responsive to a plurality of core control  
5 signals;  
decoding means for decoding P bits of an X-bit program  
instruction word of a first instruction set to generate said core  
control signals;  
an instruction pipeline through which instruction program words  
10 are passed to said decoding means; and  
first mapping means responsive to a Y-bit program instruction  
word of a second instruction set passing along said instruction  
pipeline for mapping Q bits of said Y-bit program instruction word to  
said P bits of a corresponding X-bit program instruction word for  
15 decoding by said decoding means, wherein  
Y is less than X, and said second instruction set is a subset of  
said first instruction set.
2. Apparatus as claimed in claim 1, comprising an instruction  
20 register for holding an X-bit instruction being executed by said  
processor core, said processor core reading operand values from said  
instruction register.
3. Apparatus as claimed in claim 2, comprising second mapping means  
25 for mapping operand values within said Y-bit program instruction word  
within said instruction pipeline to corresponding positions within said  
corresponding X-bit program instruction word and storing said mapped  
operand values in said instruction register for use by said processor  
core.
- 30 4. Apparatus as claimed in claim 3, wherein said second mapping  
means maps said Y-bit program instruction word to a complete version of  
said corresponding X-bit program instruction word and stores said  
complete version of said corresponding X-bit program instruction word  
35 in said instruction register.
5. Apparatus as claimed in any one of the preceding claims, wherein



instruction program words pass through said instruction pipeline over a plurality of processing cycles, one of said processing cycles being a decode cycle, said decoding means being operative to produce said core control signals by the end of said decode cycle and said first mapping means being operative to produce said P-bit of said corresponding X-bit program instruction word during a first portion of said decode portion to enable said decoding means still to produce said core control signals by the end of said decode cycle.

6. Apparatus as claimed in claims 3 and 5, wherein said second mapping means is operative to store said mapped operand values in said instruction register by the end of said decode cycle.

7. Apparatus as claimed in claim 3, wherein said second mapping means operates in parallel with said first mapping means.

8. Apparatus as claimed in any one of the preceding claims, wherein said processor core has a plurality of registers used by said first instruction set and defined as register operands within some of said X-bit program instruction words and said second instruction set uses a subset of said registers defined as register operands within some of said Y-bit program instruction words.

9. Apparatus as claimed in claims 3 and 8, wherein said second mapping means extends said register operands of said Y-bit program instruction words to produce said register operands of said X-bit program instruction words.

10. Apparatus as claimed in claim 3, wherein said operands of said X-bit program instruction words have a greater range than said operands of said Y-bit program instruction words and said second mapping means high order zero extends said operands from said Y-bit program instruction words to yield said operands of said X-bit program instruction words.

11. Apparatus as claimed in any one of the preceding claims, wherein P is less than X.

16

12. Apparatus as claimed in any one of the preceding claims, wherein Q is less than or equal to P.

5 13. Apparatus as claimed in any one of the preceding claims, wherein X is 32 and Y is 16.

14. Apparatus as claimed in any one of the preceding claims, wherein said apparatus is an integrated circuit.

10 15. A method of processing data, said method comprising the steps of:  
a processor core responsive to a plurality of core control signals;

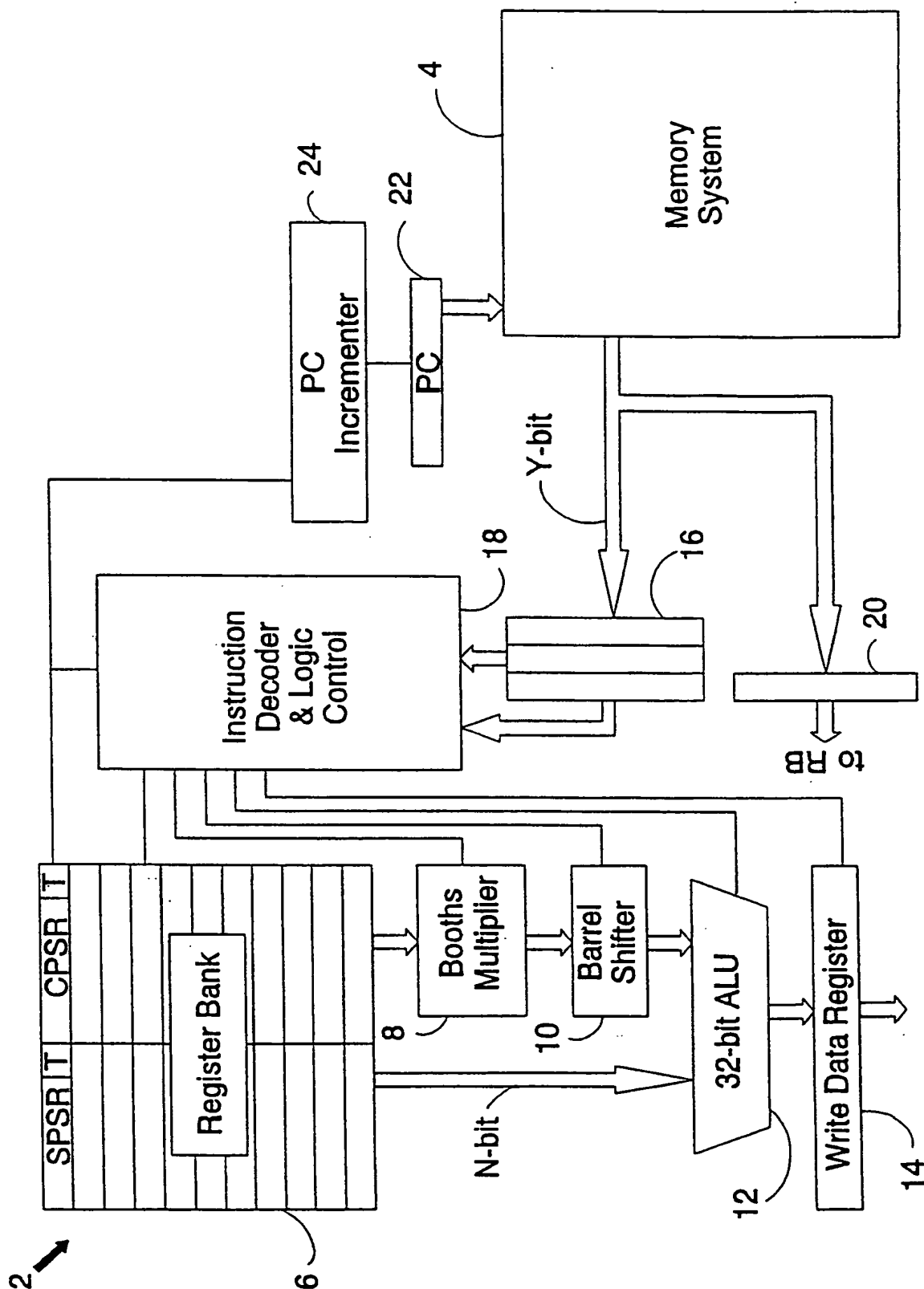
15 decoding P bits of an X-bit program instruction word of a first instruction set with a decoding means to generate core control signals for controlling a processor core;

passing instruction program words through an instruction pipeline through to said decoding means; and

20 mapping Q bits of a Y-bit program instruction word of a second instruction set passing along said instruction pipeline to said P bits of a corresponding X-bit program instruction word for decoding by said decoding means, wherein

Y is less than X, and said second instruction set is a subset of said first instruction set.

25



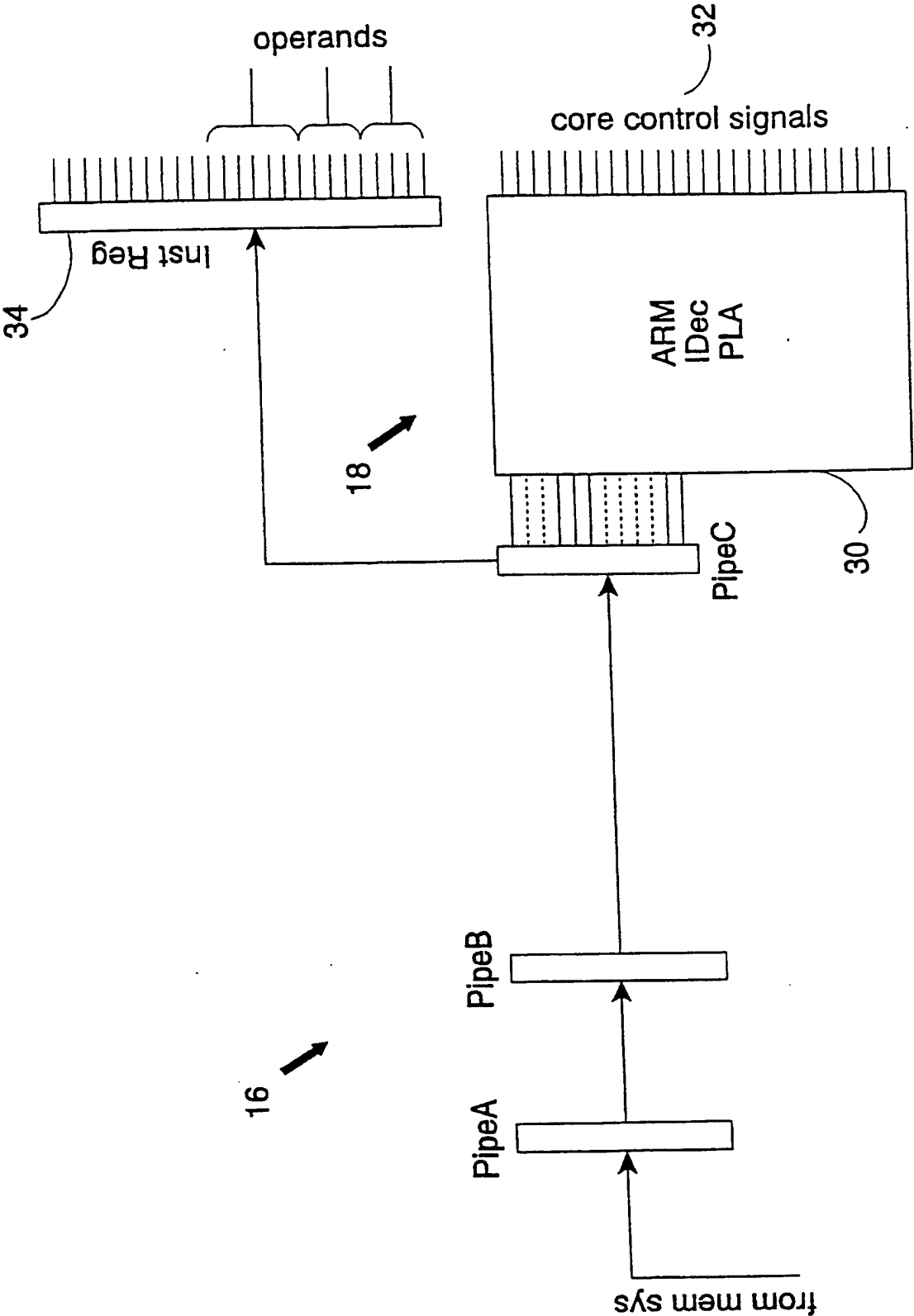


Fig.2

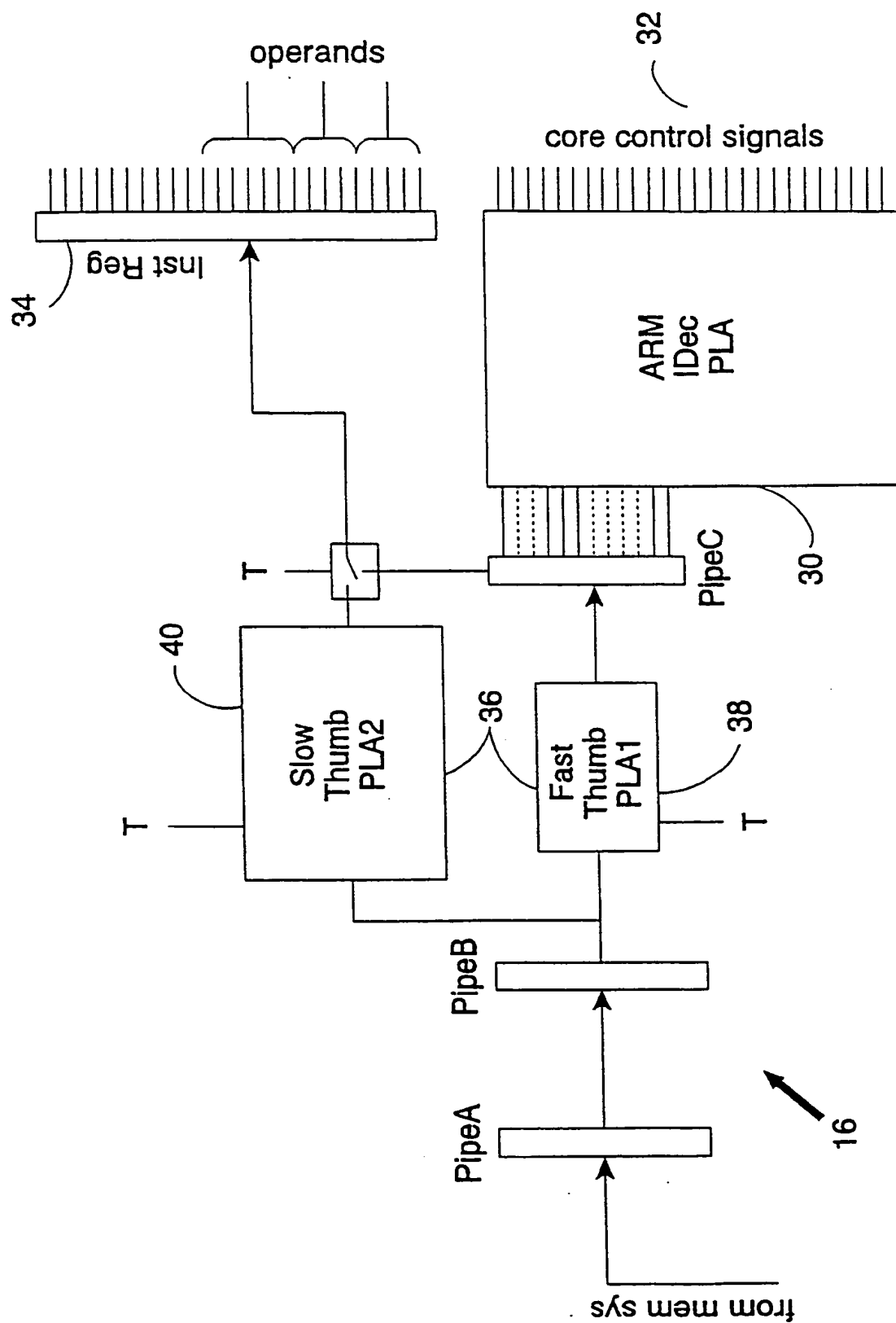


Fig.3

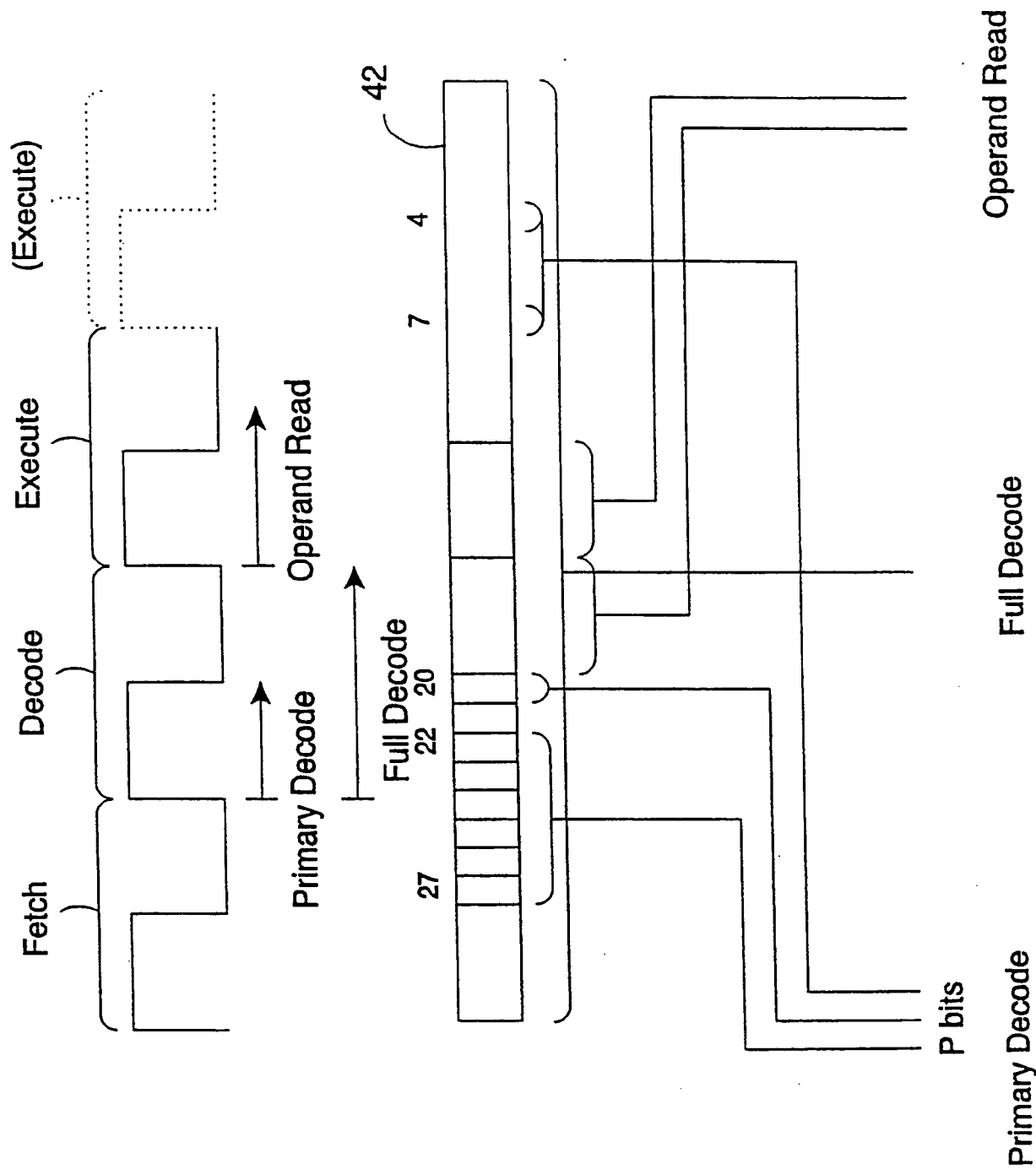


Fig.4

Load/Store Word (Byte), signed 3 bit Immediate Offset, Forced Writeback, Post Inc/Dec

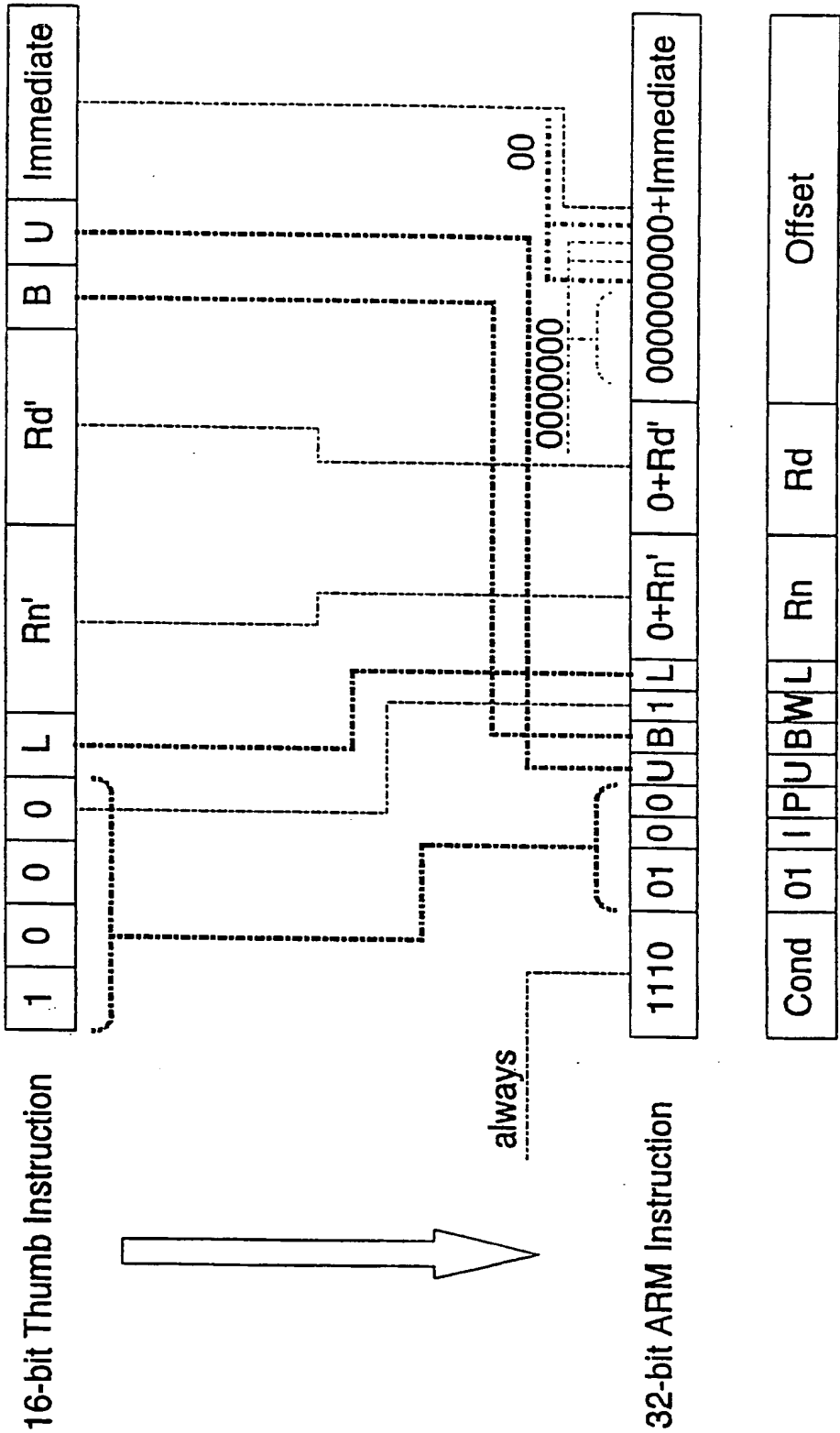


Fig.5

Load/Store Word (Byte), signed Register Offset, No Writeback, Pre Inc/Dec

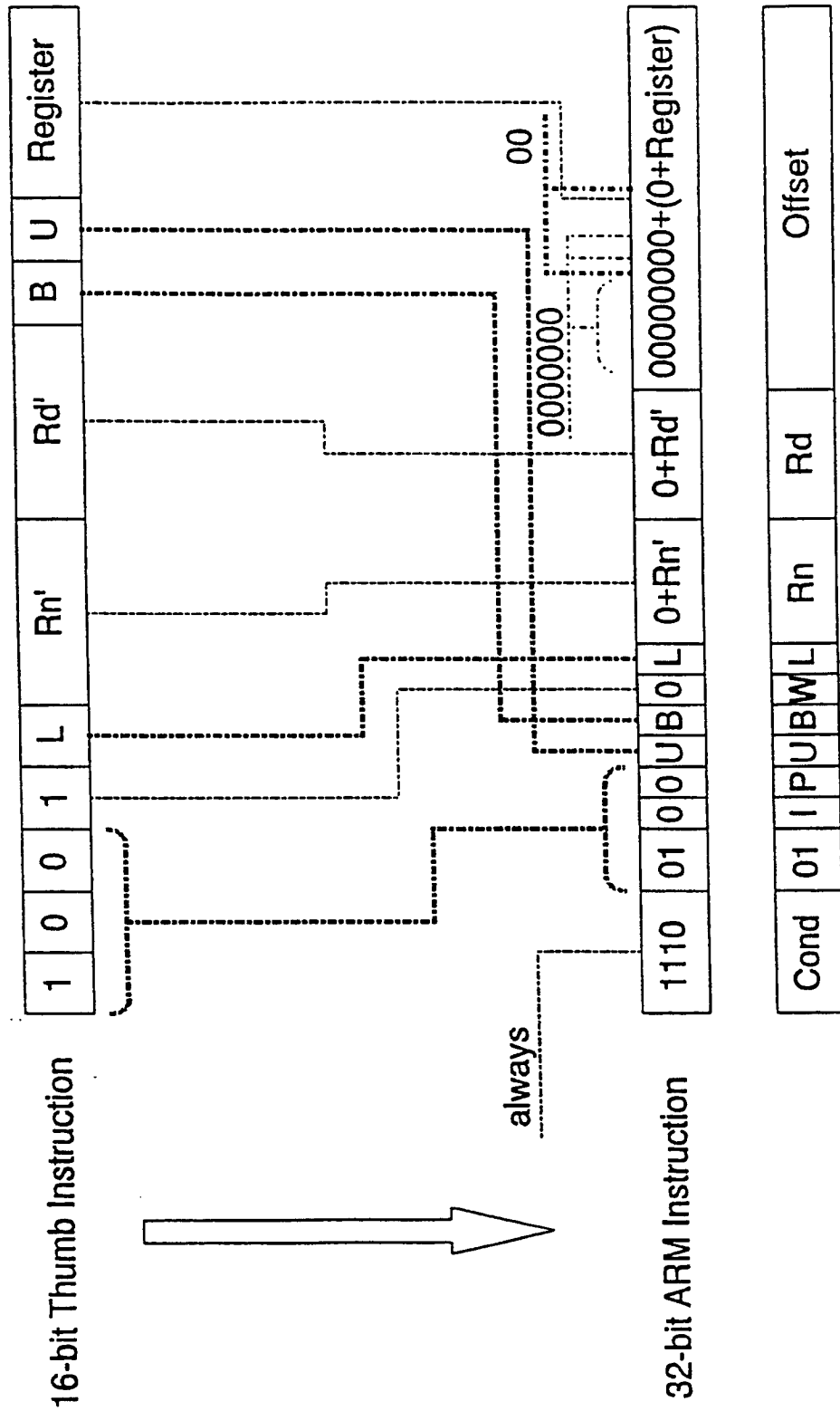


Fig.6



31		28	27	28	25	24	23	22	21	20	19	16	15	12	11	8	7	5	4	3	0	
Cond		00		1	OpCode			S		Rn			Rd			Operand2						
Cond		000000			A		S	Rd			Rs		1001		Rm							
Cond		00010			B		00	Rd			0000		1001		Rm							
Cond		01	I	P	U	B	W	L	Rn			Rd			Offset							
Cond		011			xxxxxxxxxxxxxxxxxxxx										1		xxxx					
Cond		100			P	U	S	W	L	Rn			Register List									
Cond		101			L	Offset										Offset						
Cond		110			P	U	N	W	L	Rn			CRd		CP#		Offset					
Cond		1110			CP Opc			CRn			CRd		CP#		CP		0		CRm			
Cond		1110			CP Opc			CRn			Rd		CP#		CP		1		CRm			
Cond		1111			Ignored by processor																	

Fig.7

8/9

15	14	13	12	11	10		8	7		5	4	3	2		0
0	0	0	00		Rd		Rs		0	OP	Immediate				
0	0	0	00		Rd		Rs		1	OP	Register				
0	0	0	OP=1-3		Rd		Immediate								
0	0	0	OP=0-2		Rd		Rs		Immediate						
0	0	1	1	1	OP1		Rd/Rs1		OP2		Rs2				
0	1	0	OP		Rd/Rs		Immediate								
0	1	0	1	1	Rd		PC Relative Offset								
0	1	1	B	L	Rd/Rs		SP Relative Offset								
1	0	0	0	L	Rn		Rd/Rs		B	U	Immediate				
1	0	0	1	L	Rn		Rd/Rs		B	U	Register				
1	0	1	B	L	Rn		Rd/Rs		Immediate						
1	1	0	0	L	Rn		Register List								
1	1	0	1	SP	Rd		Effective Address Offset								
1	1	1	0		Cond		8 Bit Branch Offset								
1	1	1	1	0			Long Branch and Link Segment								
1	1	1	1	1			Long Branch and Link Offset								

Fig.8

Thumb Register	ARM Register
General Register 0	General Register 0
General Register 1	General Register 1
General Register 2	General Register 2
General Register 3	General Register 3
General Register 4	General Register 4
General Register 5	General Register 5
General Register 6	General Register 6
General Register 7	General Register 7
	General Register 8
	General Register 9
Stack Limit	General Register 10
	General Register 11
	General Register 12
Stack Pointer	Stack Pointer (R13)
Link Register	Link Register (R14)
Program Counter	Program Counter (R15)
CPSR	CPSR
SPSR	SPSR

*Fig.9*

## INTERNATIONAL SEARCH REPORT

Internat. Application No  
PCT/GB 95/00314

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 G06F9/318

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 15, no. 3, August 1972 NEW YORK US, page 920 J. C. KEMP 'Instruction Translator' see the whole document ---	1-4, 11-15
Y	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 32, no. 10A, 1 March 1990 page 349 XP 000083346 'OPCODE REMAP AND COMPRESSION IN HARD-WIRED RISC MICROPROCESSOR' see the whole document ---	1-4, 11-15
A	EP, A, 0 109 567 (IBM) 30 May 1984 see the whole document ---	1, 15
-/--		

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

## \* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\* & \* document member of the same patent family

Date of the actual completion of the international search

31 May 1995

Date of mailing of the international search report

12.06.95

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl,  
Fax (+ 31-70) 340-3016

Authorized officer

Daskalakis, T

# INTERNATIONAL SEARCH REPORT

Internat. Application No

PCT/GB 95/00314

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 17, no. 11, April 1975 NEW YORK US, pages 3438-3441, P. F. SMITH 'Extended Control for Microprocessors' see the whole document ---	1, 15
A	PATENT ABSTRACTS OF JAPAN vol. 007 no. 073 (P-186) ,25 March 1983 & JP,A,58 003040 (NIPPON DENKI KK) 8 January 1983, see abstract -----	

# INTERNATIONAL SEARCH REPORT

### Information on patent family members

Internal Application No

PCT/GB 95/00314

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0109567	30-05-84	WO-A- 8401635	26-04-84
		EP-A- 0124517	14-11-84
		US-A- 4587612	06-05-86
-----			